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GRAPHING TECHNIQUES FOR MATERIALS LABORATORY USING EXCEL

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KEY WORDS: Spring rate, stress concentration, endurance limit, column buckling, linear regression, slope-intercept, logarithmic graphing.

PREREQUISITE KNOWLEDGE: Students should have a course in computer literacy and some knowledge in strength of materials including stress-strain, cyclic loading, and column buckling.

OBJECTIVES: To introduce the use of Microsoft Excel spreadsheet for data reduction and evaluation of experimental results. This paper is intended to serve as a tutorial with a number of sample experiments on a strength of materials course.

INTRODUCTION

Engineering technology curricula stress hands on training and laboratory practices in most of the technical courses. Laboratory reports should include analytical as well as graphical evaluation of experimental data. Experience shows that many students neither have the mathematical background nor the expertise for graphing.

This paper briefly describes the procedure and data obtained from a number of experiments such as spring rate, stress concentration, endurance limit, and column buckling for a variety of materials. Then with a brief introduction to Microsoft Excel the author explains the techniques used for linear regression and logarithmic graphing.

GENERAL GRAPHING PROCEDURE

The concepts one needs to know on Microsoft Excel worksheet are shown in figure 1. Arrange the data such that all the X values are in the first column of the data area to be selected for graphing. The first row of data is usually column headings and is displayed in the legend. The second column is the Y values for the first curve and the third column is the Y values for the second curve and so on.

Highlight the data to be graphed and select the type of graph by clicking on FILE _ NEW _ CHART _ OK. A bar graph is displayed as default. Now GALLERY shows up in the menu bar. Select GALLERY _ X (select an appropriate number for the desired type of graph for X)

To add legend highlight the data table including the legend and click on the CHART menu when a dialog box is displayed. Click on ADD LEGEND.

To add text for title and axes click on

CHART _ ATTACH TEXT _ CHART TITLE _ OK. A set of squares appear on the graph. Type the title,

ENTER, and then click the mouse with the arrow on the graph. Go back to chart menu and click on ATTACH TEXT and repeat the same procedure for CATEGORY AXIS and VALUE AXIS

Entering data, graphing techniques and printing of your work are explained step by step with the help of experimental data in the following. Experiments are selected to give readers a general overview of mostly used graphing assignments.

EXPERIMENTS

Spring Rate:

Spring rate is the amount of load that is required to compress the spring per unit of deflection. The data table shows the force(lb) used to compress a spring causing a reduction in length(in) recorded as deflection.

This is an example of a set of curves including legend, title, and axes. This graph also demonstrates the linear regression technique using the LINEST function.

Worksheet 1. Spring Rate:

Click the mouse on FILE _ NEW - WORKSHEET _ OK

Enter title at the top, pick cell C3 and highlight C3:D3 with the mouse, change the font style, font type, and size as follows:

FORMAT _ FONT _ BOLD _ SIZE 10 _ OK

Create column headings

Select cell and type text using appropriate font settings.

Enter data:

For the graph start column with zeros. Type the load data in A6 to A11 and spring A deflection data in B6 to B11.

To change the precision of the displayed value highlight the column, click FORMAT _ NUMBER, position the cursor at the CODE bar and type in 0.000 _ OK.

Slope-Intercept Formula / Linear Regression:

Assign names to columns

Select the cell and highlight the selected column (do not include zeros), click

Click on FORMULA _ DEFINE NAME _ type in name (example: A for column A) _ OK

Create title for slope-intercept in the cells as shown:

To enter the slope-intercept function LINEST for spring A highlight the two adjacent cells below the slope intercept titles, type the formula for spring A exactly as

=LINEST(B,A) where B is the name of the second column and A is the name of the first column as

defined earlier. Press and hold **CONTROL + SHIFT** and press **ENTER**. The slope and intercept values are now displayed in the selected cells.

Linear Regression:

The linear regression (L.R.) column for spring A is created by entering the slope - intercept formula in cell C6 as $=\$A\$14*A6+\$B\14 _ ENTER, once entered click **EDIT _ COPY** highlight cells C7:C11 _ ENTER. (C7:C11 means cell C7 through cell C11)

Repeat for spring B using column E for load, column F for deflection, and column G for slope-intercept formula.

Graphing Spring Rate (figure 2):

Highlight A5:C11, press and hold **CONTROL** and highlight F5:G11

Select **FILE _ NEW _ CHART _ OK**, bar graph is displayed, click on **GALLERY**, pick #5 _ OK.

at **CHART** menu click on **ADD LEGEND**

at **CHART** menu click on **ATTACH TEXT _ CHART TITLE _ OK**

type title **SPRING RATE** _ ENTER, click mouse

click on **CHART _ ATTACH TEXT _ CATEGORY AXIS _ OK**

type **LOAD(lb)**, click mouse

click on **CHART _ ATTACH TEXT _ VALUE AXIS _ OK**

type **DEFLECTION(in)** _ ENTER, click mouse

click on **CHART _ ADD ARROWS**, position mouse at the arrow ends, press and hold and move to the desired location

type **SPRING A** for the first spring

repeat for spring B

Stress Concentration

The presence of shoulders, grooves, keyways, threads, or any type of discontinuities in machine elements results in modification of simple stress distribution.

In this experiment force is applied at the end of a cantilever beam with a hole creating stress proportional to the deflection. Purpose of this experiment is to measure stress level at various distances from the hole. Strain gages are installed at the desired locations on the beam for stress readings. The experimental data is displayed in the given table.

Worksheet 2. Stress Concentration:

Type **STRESS CONCENTRATION** in B2 _ ENTER

type **Gage #1**, **Gage #2**, **Gage #3**, and **Gage #4** in B4, C4, D4, and E4

type data table as given in A5:E9

Graphing Stress Concentration (figure 3):

highlight A4:E9

click on FILE _ NEW _ CHART _ OK

click on GALLERY _ LINE _ 5 _ OK

click on CHART _ ADD LEGEND _ OK

click on CHART _ ATTACH TEXT _ CHART TITLE _ OK, click

type STRESS CONCENTRATION _ ENTER, click

click on CHART _ ATTACH TEXT _ CATEGORY AXIS _ OK

type DEFLECTION(in) _ ENTER, click

click on CHART _ ATTACH TEXT _ VALUE AXIS _ OK

type STRESS(psi) _ ENTER, click

Printing :

click on FILE _ PRINTER SET UP

click on SET UP _ LANDSCAPE _ NLQ _ OK _ OK

click on FILE _ PRINT _ PREVIEW _ OK

click on ZOOM for close observation

click on PRINT

Endurance Limit:

Endurance limit is a material property expressed in terms of stress(psi) that can be endured during cyclic loading regardless of the number of applied cycles. This stress value is also called the fatigue limit.

In this experiment a 1/4" diameter grooved shaft is rotated under load till failure. The data table shows the groove distances from the loading point X, Groove diameter d, Load plus the weight of the fixture P, Accumulated number of cycles N, and the stress S.

Worksheet 3. Endurance Limit:

Type in the worksheet as shown, calculate the stress values using P, d, X, and Kt (=1).

Select cell E24

type formula for stress $S = 32*P*X/(3.14*d*d*d)$ in the worksheet as

$=32*C24*A24/(3.14*B24*B24*B24)$ and click on E24,

stress value is displayed in E24

select E24 _ COPY, highlight E25:E29 _ ENTER, stress values are displayed in column E.

Graphing Endurance Limit (figure 4):

highlight D23:E28

FILE _ NEW _ CHART _ OK

GALLERY _ SCATTER _ 5 _ OK

Enter necessary texts for the graph and print.

Column Buckling

Long columns and the more slender short columns usually fail by buckling when critical load is reached. In this experiment the critical load for 1/4" diameter and 12", 16", 20", and 24" long rods is determined.

Worksheet 4. Column Buckling:

Type the title COLUMN BUCKLING DATA SHEET in B1

click on FORMAT _ FONT _ HELV BOLD _ OK

type EXPERIMENTAL in B2

type the data table exactly as shown.

If you highlight B3:E6 column B is considered as the category axis and if you highlight A3:E6 column A serves as legend with row 3 as category axis.

highlight A3:E3

click on FORMAT _ BORDER _ SHADE _ OUTLINE _ OK, click

Graphing Column Buckling (figure 5):

highlight A3:E6

click on FILE _ NEW _ CHART _ OK

click on GALLERY _ LINE _ 6 _ OK

click on CHART _ ADD LEGEND _ OK

click on CHART _ ATTACH TEXT _ CHART TITLE _ OK

type COLUMN BUCKLING _ ENTER, click

click on CHART _ ATTACH TEXT _ CATEGORY AXIS _ OK

type LENGTH(in) _ ENTER, click

click on CHART _ ATTACH TEXT _ VALUE AXIS _ OK

type LOAD(lb) _ ENTER, click

Follow the previous instruction for printing.

REFERENCES:

1. Eliason, A. L., *Microsoft Excel Student Edition*, Prentice Hall, 1993.
2. Denton, Hillsman, Roach, and Thelen, *Strength of Materials-Laboratory Manual*, Purdue University, Mechanical Engineering Technology, 1993.

Concepts You Need to Know

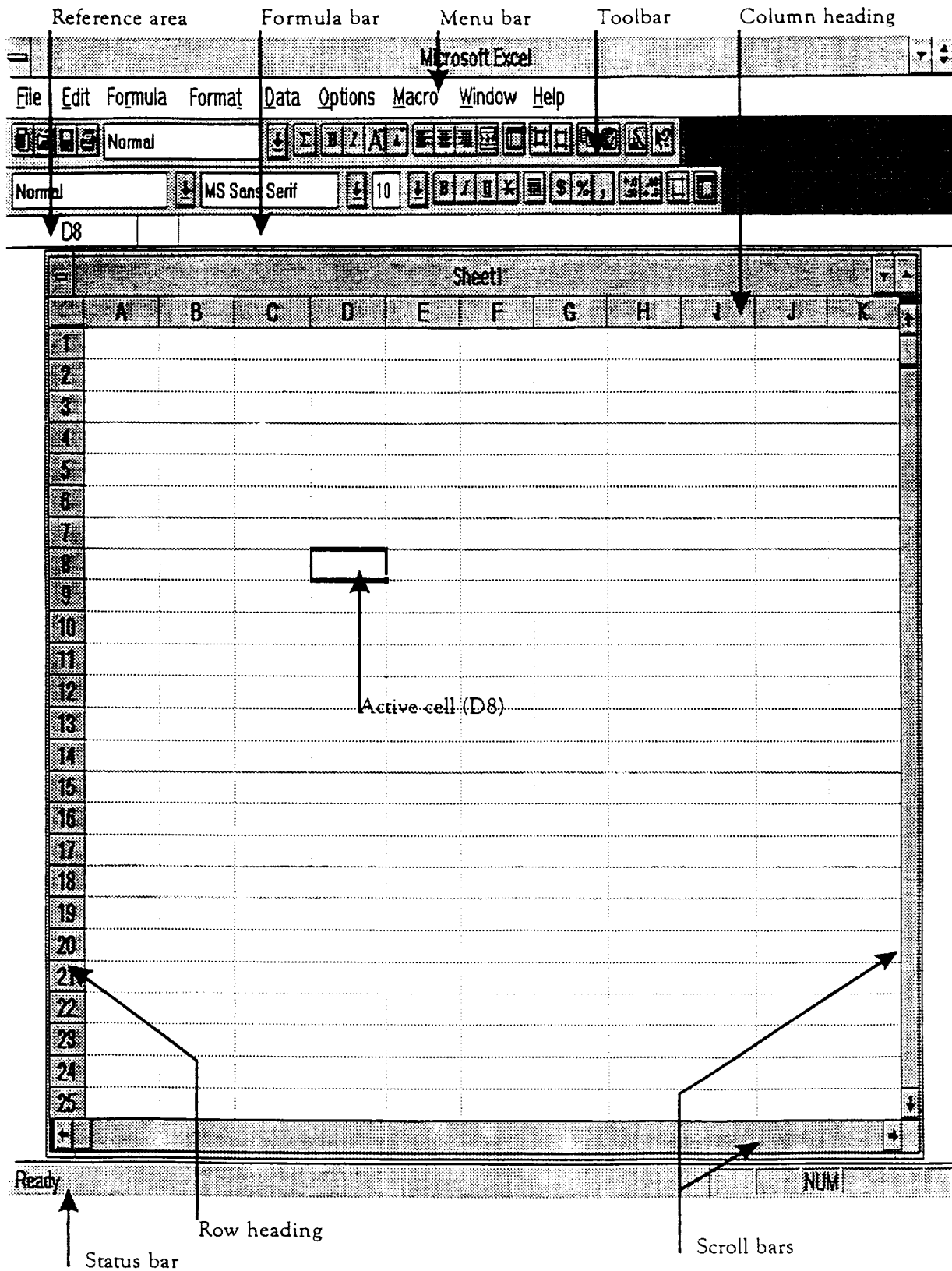
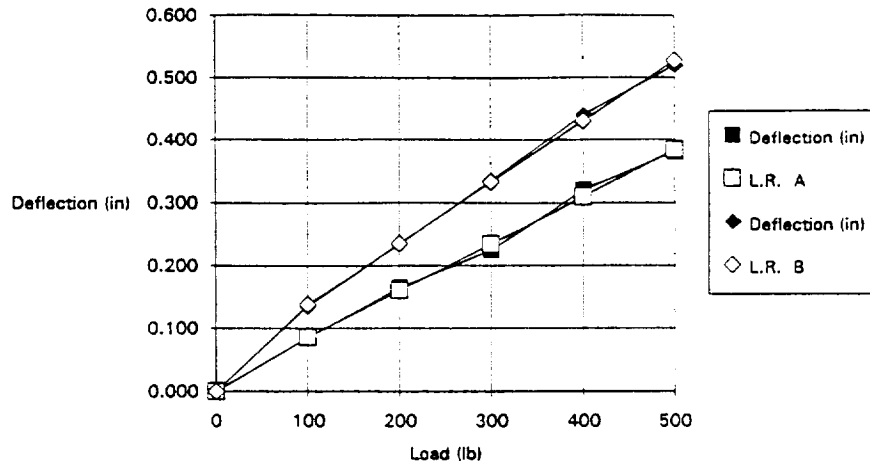


Figure 1

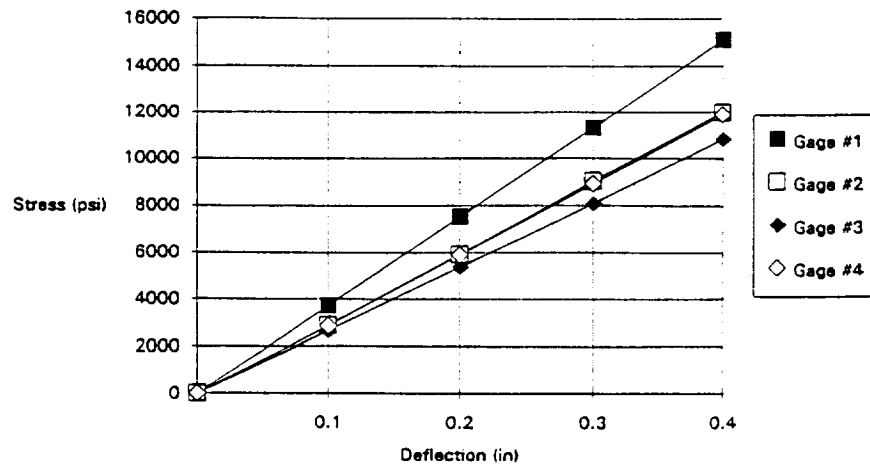
	A	B	C	D	E	F	G
1	Worksheet 1	Spring Rate:					
2							
3		SPRING RATE					
4							
5		Deflection (in)	L.R. A		Deflection (in)	L.R. B	
6	0	0.000	0.000		0	0.000	0.000
7	100	0.085	0.086		100	0.135	0.138
8	200	0.185	0.161		200	0.235	0.236
9	300	0.225	0.235		300	0.335	0.333
10	400	0.320	0.310		400	0.440	0.431
11	500	0.380	0.384		500	0.520	0.528
12							
13	Slope	Intercept			Slope	Intercept	
14	0.000745	0.0115			0.000975	0.0405	

Figure 2. Spring Rate



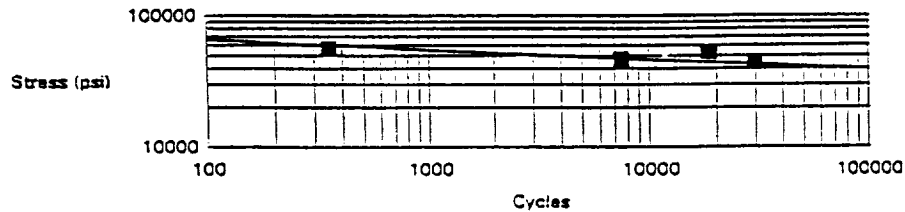
	A	B	C	D	E
1	Worksheet 2. Stress Concentration				
2					
3	Stress Concentration				
4	Gage #1	Gage #2	Gage #3	Gage #4	
5		0	0	0	0
6	0.1	3730	2900	2660	2870
7	0.2	7520	5930	5380	5900
8	0.3	11320	9030	8070	8920
9	0.4	15120	12010	10840	11900

Figure 3. Stress Concentration

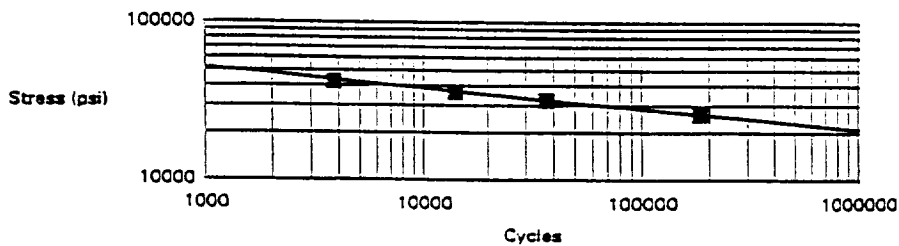


	A	B	C	D	E
1	Worksheet 3. Endurance Limit:				
2					
3			ALUMINUM		
4	X	d	P	N	S
5					
6	20.6875	0.294	6.80916	346	56491.08
7	18.1875	0.3	6.80916	7406	46743.7
8	15.6875	0.274	6.80916	18175	52919.52
9	13.1875	0.274	6.80916	29404	44486.13
10	10.6875	0.274	6.80916		
11					
12			BRASS		
13	X	d	P	N	S
14					
15	20.6875	0.298	5.3021	3748	42240.35
16	18.1875	0.3	5.3021	13947	36398
17	15.6875	0.298	5.3021	36871	32031.2
18	13.1875	0.301	5.3021	179778	26129.51
19	10.6875	0.299	5.3021		
20					
21			STEEL		
22	X	d	P	N	S
23					
24	19.25	0.279	13.2614	1725	119792
25	16.75	0.279	13.2614	3878	104234.6
26	14.18	0.279	13.2614	7481	88241.59
27	11.75	0.279	13.2614	16259	73119.79
28	9.28	0.279	13.2614	53230	57749.08

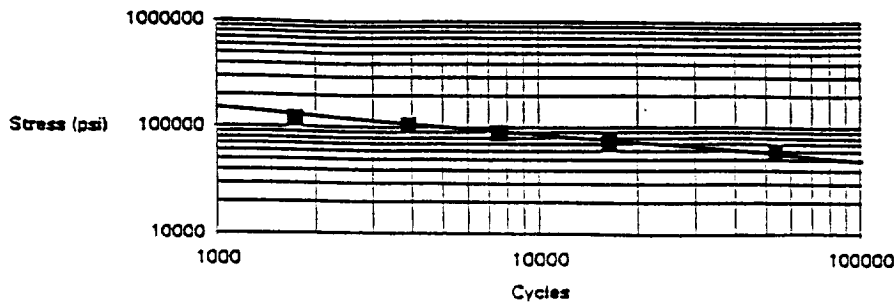
Figure 4. Endurance Limit for Aluminum



Endurance Limit for Brass



Endurance Limit for Steel



	A	B	C	D	E
1	Worksheet 4. Column Buckling				
2					
3		12	16	20	24
4	Steel	425	220	138	115
5	Aluminum	130	62	50	35
6	Brass	95	70	45	30

Figure 5. Column Buckling

